

Experimental analysis of fingerprint techniques: variance and ROC

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Abstract

The objective of this paper is to analyze the fingerprint verification techniques by extracting the features of fingerprints and enhance the fingerprint using image processing techniques to improve the matching percentage. It aims to perform the analysis on the matching results as FAR and FRR. Observe the ROC receiver operating characteristic curves. The method results in more time robust matching and enhance the correlation values between two fingerprints. It is however equally important that the image enhancing process does not suppress distinct features since this would affect identification or verification process negatively leading to false mismatches or in worst case, to false matches. It is observed that enhancing the coherence in the fingerprint images the variance of FMR and FNMR is 0.000259 & 0.71 respectively.

Keywords: Fingerprint; FMR; FNR; ROC; variance.

Introduction

Fingerprint recognition is still a challenging. With the increase in the number of commercial systems for fingerprint-based recognition, proper evaluation protocols are needed. The first fingerprint verification competition (FVC2000) was a good start in establishing such protocols. As fingerprints (biometrics) get increasingly embedded into various systems (e.g., cellular phones, laptops), it becomes increasingly important to analyze the fingerprint verification as well as identification on the overall integrity of the system and its social acceptability as well as the related security and privacy issues (Mansfield, 2002).

Research methodology

It involves two representation forms for fingerprints and their features separate the two approaches for fingerprint recognition i.e., minutiae based matching and correlation based matching.

The first approach, which is minutia-based, in which fingerprint comparison is made by extracting minutia from two fingerprints and stored a set of points in two dimensional planes. Here ridge ending and bifurcation are considered as a minutiae (Espinosa-Duro, 2002). This approach has been intensively studied; this technique is the backbone of the current available

fingerprint recognition products. Concentrating on this approach in our experiment we make the analysis of each step and observe the result for both genuine and imposter fingerprints available the DB3 database.

The second approach, which is correlation based (Maltoni *et al.*, 2003) in which two fingerprints are superimposed and correlation between corresponding pixels is computed for different alignments as displacement and rotation. The correlation values are improved using wavelet tool box in the MATLAB. Here using the FFT i.e. Fast fourier Transform and wavelet decomposition find the correlation values (Rafael Gonzalez *et al.*, 2007).

Experimental analysis

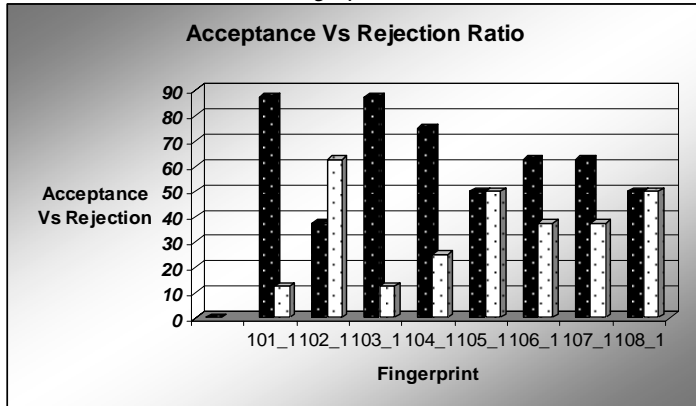
Considering the fingerprint database DB3 available in public domain, experimental analysis are carried out for both genuine and imposter fingerprint using the program developed in MATLAB (Maltoni *et al.*, 2003). Minutiae based matching percent is computed for genuine identifier. By considering some threshold value for percentage, the number of matched and non-matched fingerprints are evaluated to calculate FAR and FRR (Jinwei Gu *et al.*, 2004).

Verification is done where the correlation values are also calculated for different set of fingerprint. It is

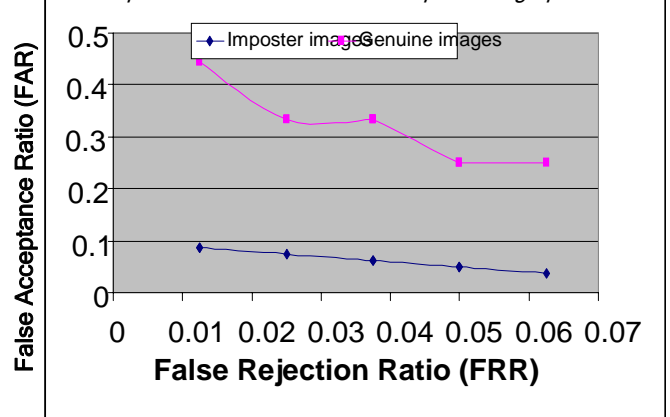
Table 1. Minutiae matching percent of genuine fingerprints

Finger	Percent match (101_1)	Finger	Percent match (102_1)	Finger	Percent match (103_1)	Finger	Percent match (104_1)	Finger	Percent match (105_1)
101_1	100.00%	102_1	100.00%	103_1	100.00%	104_1	100.00%	105_1	100.00%
101_2	50.00%	102_2	23.61%	103_2	41.37%	104_2	36.17%	105_2	42.42%
101_3	31.81%	102_3	34.72%	103_3	53.44%	104_3	44.68%	105_3	30.30%
101_4	31.81%	102_4	26.38%	103_4	31.03%	104_4	51.06%	105_4	21.21%
101_5	40.09%	102_5	23.61%	103_5	39.65%	104_5	42.55%	105_5	18.18%
101_6	31.81%	102_6	26.38%	103_6	34.48%	104_6	25.53%	105_6	27.27%
101_7	27.27%	102_7	30.55%	103_7	37.93%	104_7	25.53%	105_7	22.58%
101_8	36.36%	102_8	27.77%	103_8	20.68%	104_8	40.42%	105_8	30.30%

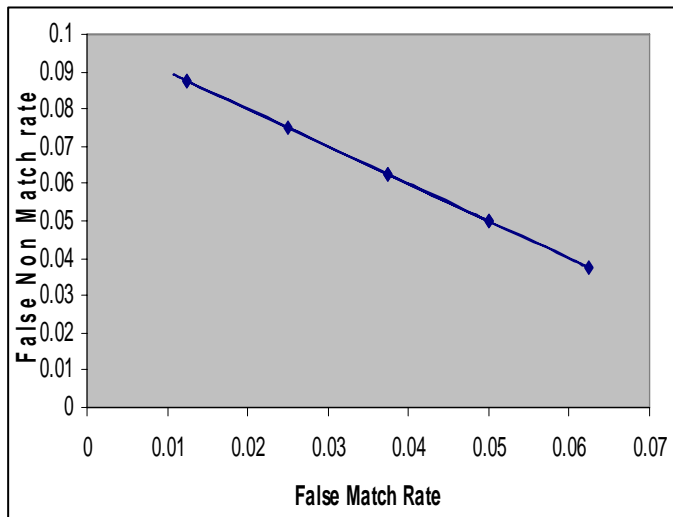
Graph 1. Histogram of matched and non- matched fingerprint



Graph 3. ROC for Genuine and imposter fingerprints



Graph 2. ROC curve for genuine and imposter matcher



Graph 4. Comparison of statistical and experimental analysis

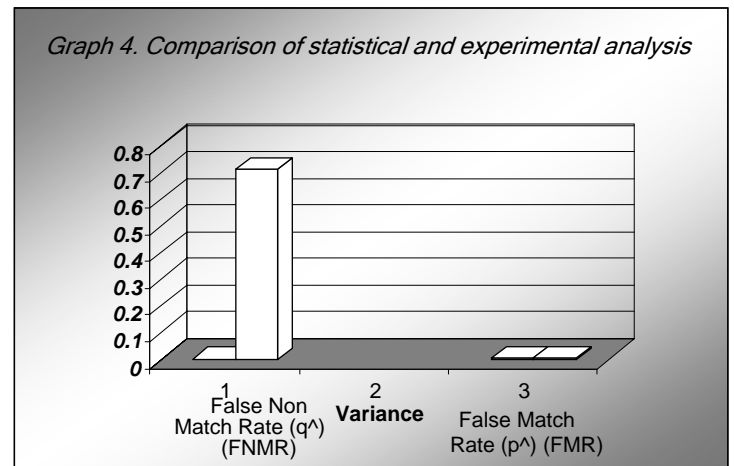


Table 2. Matched and non matched fingerprint

Finger	No. of matched fingerprint	No. of non matched fingerprint
101_1	7	1
102_1	3	5
103_1	7	1
104_1	6	2
105_1	4	4
106_1	5	3
107_1	5	3
108_1	4	4

Table 3: Percentage of matched and non matched fingerprints

Fingerprint images	Acceptance ratio	Rejection ratio
101_1	87.5	12.5
102_1	37.5	62.5
103_1	87.5	12.5
104_1	75	25
105_1	50	50
106_1	62.5	37.5
107_1	62.5	37.5
108_1	50	50

Table 4. FMR and FNMR for DB3 database

Finger	FMR	FNMR
101_1	0.0875	0.0125
102_1	0.0375	0.0625
103_1	0.0875	0.0125
104_1	0.075	0.025
105_1	0.05	0.05
106_1	0.0625	0.0375
107_1	0.0625	0.0375
108_1	0.05	0.05

Table 5. FMR and FNMR for genuine and imposter fingerprints

FNR	FMR for genuine fingerprints	FMR for imposter fingerprints
0.0125	0.0875	45.00%
0.0125	0.0875	44.44%
0.025	0.075	33.33%
0.0375	0.0625	33.33%
0.0375	0.0625	33.33%
0.05	0.05	25.00%
0.05	0.05	25.00%
0.0625	0.0375	25.00%

Table 6. Variance of FMR and FNR rate

Observation	False Match Rate (p^)(FMR)	False Non Match Rate (q^)(FNMR)
Variance	0.000259	0.71

observed that the two images are matched where the correlation of the matrices of the images is 1. Observations (Table 1) are taken to find the matching percentage of fingerprints from the database DB: fingerprint3 which are also used for different analysis of the performance of different fingerprint matching algorithm in the FVC2004 competition.

Considering the matching percent threshold 30%, the number of fingerprint matches and non-matches using minutiae based matching from DB3 Database are shown in Table 2. The percentage of acceptance ratio and rejection ratio is shown below in Table 3.

Variance of observed false non-match rate

Formula for estimating the variance of the false non-match rate for cases when there is a single sample per volunteer, and when there are multiple attempts per volunteer is:

$$m = \frac{1}{2} \sum_i m_i$$

Where,

- n: number of enrolled volunteers;
- mi: number of samples from the ith volunteer;

These formulae will also be appropriate for estimating variances of failure to acquire rates and failure to enroll rate.

There for m is the average number of samples per volunteer.

ai: number of false non-matches for the ith volunteer;

pi = ai/mi : proportion of unmatched samples for the ith volunteer;

\hat{p} : observed false non-match rate over all volunteers;

$\hat{V}(\hat{P})$: estimated variance of observed false non-match rate.

According to the above analysis of our database,

n= 10

mi = 80

So, m = 80/10

m = 8 average no. of samples per volunteer

a i= 3 number of false

non-matches for the ith volunteer; Here i.e. (6th & 7th)

pi = ai/mi proportion of unmatched samples for the ith volunteer;

$$= 3/80 * 100 = 0.0375 * 100 = 3.75 \%$$

For single attempt per volunteer

In the case where each of n volunteers makes a single attempt:

$$\hat{p} = \frac{1}{n} \sum a_i$$

$$\hat{V}(\hat{P}) = \frac{\hat{p}(1-\hat{p})}{n-1}$$

Note: This formula has sometimes been misapplied to cases where subjects make several attempts. The replacement of the number of subjects n, by the number of attempts nm, is generally not valid.

$$\sum a_i = 23$$

$$\hat{P} = (1/80) * 23 = 0.2875$$

$\hat{V}(\hat{P}) = 0.2875(1-0.2875)/79$; estimated variance of observed false non-match rate.

$$\hat{V}(\hat{P}) = 2.59 \text{ e-4}$$

Variance of observed false match rate

The variance of the false match rate where the case is for a full set of cross comparisons.

n number of volunteers (and of enrolment templates);

m number of samples per volunteer;

b_{ij} number of samples from the ith volunteer falsely matching the jth template (and b_{ii}=0);

$$c_j = \sum_i b_{ij}$$

: is number of false matches against the jth template;

$$d_i = \sum_j b_{ij}$$

: number of false matches in total by the ith volunteer.

$$\hat{q} = \frac{\sum_{ij} b_{ij}}{mn(n-1)}$$

Then the observed false match rate is

Here $\sum b_i = 45$

$$\hat{q} = (1/80) * 45 = 0.56$$

$$\hat{V}(\hat{q}) = 0.56(1-0.56)/79 = 0.71$$

Considering Table 2 and 3, the false matching ratio and false non matching ratio are shown in the Table 4 and in Table 5 (for imposter fingerprint) from which the ROC curve is drawn for false matching rate against false non-match rate (Graph 2 and 3). The variance of false match rate and false non match rate are shown in Table 6.

Table 7. Correlation values for the genuine fingerprints 101_7 with 101_1

Correlation Values while de noised and compressed the image	Correlation values by applying Low pass filter
0.035220179	0.756909513
0.056046859	0.776365805
0.087469345	0.828910424
0.029973132	0.801700609
0.160750931	0.81905524
0.128375984	0.836320813
1	1
0.230651812	0.854990914

Experimental analysis of correlation based fingerprint verification

Using the wavelet functions from wavelet toolbox, decompose the fingerprint images and reconstruct it to find the correlation value of the two images. The verification of the input image is results the correlation value for both should be one (Table 7).

Considering the correlation values seen experimentally for certain threshold, the number of matches and non-matches using correlation based technique form DB3 database are shown in Table 8. The rate of false matched and non- matched rates are calculated accordingly (Table 9).

The variance of FMR and FMNR by Correlation method is

$$\sum a_i = 33$$

$$\hat{p} = (1/80) * 33 = 0.412$$

$$V(\hat{p}) = 0.412(1-0.412)/79 ; \text{ estimated variance of observed false non-match rate.}$$

$$V(\hat{p}) = 0.00306$$

Here $\sum b_i = 33$

$$q^{\wedge} = (1/80) * 33$$

$$q^{\wedge} = 0.412$$

$$V(q^{\wedge}) = 0.412(1-0.412)/79$$

$$V(q^{\wedge}) = 0.00306$$

Variance p^{\wedge} and q^{\wedge} by correlation matching

Comparison of statistical and experimental analysis

According to Table 6 and 10, the comparison for both statistical and experimental analysis of fingerprint matching are given in Table 11.

Conclusions

Experimentally combined fingerprint matching and verification method was done by building a minutia extractor and a minutia matcher. Also it uses the correlation technique for fingerprint matching. The combination of multiple methods comes from a wide investigation into research paper.

It is an attempt on our part to show, to make familiar with at least two techniques of analysis which are widely used in the biometric system: comparing the performance analysis by experimental and statistical results. The analysis shows that the Minutiae based matching technique gives the best results since the FAR and FRR are optimal values. Receiver operating characteristic curves Receiver operating characteristic curves (ROC) summarizes the performance of imperfect diagnostic,

Table 8. Matched and non matched fingerprint by correlation

Finger	No. of Matched fingerprint	No. of Non matched fingerprint
101_1	4	4
102_1	6	3
103_1	4	4
104_1	3	5
105_1	4	4
106_1	5	3
107_1	4	4
108_1	3	6

Table 9. FMR and FMNR for DB3 database by correlation

Finger	FMR	FNR
101_1	0.05	0.05
102_1	0.075	0.0375
103_1	0.05	0.05
104_1	0.0375	0.0625
105_1	0.05	0.05
106_1	0.0625	0.0375
107_1	0.05	0.05
108_1	0.075	0.0375

Table 10 Variance p^{\wedge} and q^{\wedge} by correlation matching

Observation	False Match Rate (p^{\wedge}) (FMR)	False Non Match Rate(q^{\wedge})(FNMR)
Variance	0.00306	0.00306

Table 11. Comparison of experimental & statistical analysis

Observation	False Match Rate (p^{\wedge}) (FMR)	False Non Match Rate (q^{\wedge}) (FNMR)
Variance (Statistical)	0.000529	0.71
Variance (Experimental)	0.00306	0.00306

detection, and pattern matching systems. An ROC curve plots, parametrically as a function of the decision threshold.

Future scope

There is no end for innovation. Still researchers are eager to find the maximum fingerprint matching rate for identification and classification. As says in the justification on the differences of these algorithms, one can extract both the local and global minutiae. For the improvement in the system the core point of the fingerprint should be detected and considering core as a reference point, the two fingerprints can be matched by doing the alignment according to the core point. By extracting the level 3 features of the fingerprint like pores and ridges one can implement the matching algorithm which gives the best results, since these features can be extracted only on the high resolution fingerprint scanner of 1000 DPI.

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